

ECONOMIC EVALUATION OF CEREAL CROPPING SYSTEMS UNDER SEMIARID CONDITIONS: MINIMUM INPUT, ORGANIC AND CONVENTIONAL

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ABSTRACT: Cropping systems like organic farming, selling products at a higher price and promoting environmental sustainability by reducing fertilizer and pesticides, can be more profitable than conventional systems. An economic evaluation of three cropping systems in a seven year period experiment was performed, using a common rotation (fallow-barley-vetch-durum wheat) in a semi-arid rainfed field of Spain. The minimum input system included mouldboard ploughing, cultivator preparation, sowing and harvest. The conventional system involved mineral fertilizer and herbicide treatments, while the organic system involved composted manure and mechanical weed control. The resulting economic margins were highest with the minimum input system, followed by the organic and conventional systems. If the cereal grain from the minimum input system was sold at a higher price on the organic market, this system was the most profitable. Without the price difference, the organic system was as profitable as the conventional one.

Key words: profitability, organic agriculture, crop rotation

AValiação Econômica de Sistemas de Cultivo de Cereias em Condições Semiáridas: Cultivo Mínimo, Orgânico e Convencional

RESUMO: Sistemas de cultivo como agricultura orgânica, cujos produtos têm custo mais alto, mas que promova sustentabilidade ambiental pela redução do uso de fertilizantes e pesticidas, pode ser mais lucrativo do que sistemas convencionais de cultivo. Efetuou-se uma avaliação econômica de três sistemas de cultivo num período experimental de sete anos, utilizando um sistema comum de rotação (pousio-cevada-ervilhaca-trigo duro), sem irrigação, em um local semi-árido da Espanha. O sistema de cultivo mínimo incluía aração com aiveca, preparo com cultivador, semeadura e colheita. O sistema convencional envolvia tratamentos com herbicidas e fertilizantes minerais, enquanto o sistema orgânico envolvia adubação com composto e controle mecânico de ervas invasoras. O sistema com maior retorno econômico foi o de cultivo mínimo, seguido do orgânico e do convencional. O sistema de cultivo mínimo foi o mais lucrativo quando o cereal foi vendido num preço mais alto no mercado orgânico. Sem essa diferença de preços os sistemas apresentaram lucratividades semelhantes.

Palavras-chave: lucratividade, agricultura orgânica, rotação de culturas

INTRODUCTION

The use of mineral fertilizers and herbicides has decreased significantly in semiarid zones to reduce costs and maintain profit margins, which largely depend on subsidies from the European Union. In Spain, the yield of winter cereals in semiarid regions is low (2-3 t ha⁻¹) because yields depend more on the quantity and distribution of rainfall than on agricultural inputs (López-Bellido et al., 1996 and Angás et al., 2006).

Cropping systems like organic farming, selling products at a higher price and promoting environmental sustainability by reducing fertilizer and pesticides, can be more profitable than conventional systems (Delate et al., 2003; Pimentel et al., 2005). Nonetheless, it is reasonable to assume that yield could decrease without chemical fertilization (Pardo et al. 2008; García-Martín et al., 2007), without chemical weeding (Barberi et al., 2000) or with the organic substitutes. By contrast, other researchers indicate that good weed control and also similar yields could be achieved by using

integrated crops systems in comparison with conventional methods (Swanton et al., 2002). van Herwaarden et al. (1998) sustain that chemical fertilization does not increase yield under a semiarid climate and yields could even diminish.

Evidence in Spain indicates that yields are equal in both conventional and organic rotations (Meco et al., 1998; Lacasta & Meco, 2006; Agreda & Abós, 2001). However, most of these authors suggest that the economic profitability of the organic rotation is higher than the conventional system, although they do not perform an economic study *per se*. Moreover, the majority of these trials do not cover a long year period and then their conclusions are limited.

The aim of this study is to compare the yield and economic outputs of a conventional system with a minimum input and an organic farming system for cereal production over a long term experiment under semiarid conditions. To achieve this objective, a seven year experiment (1997-2003) was performed in a semiarid region of Spain.

MATERIAL AND METHODS

Study area and experimental design

The trials were carried out from 1997-2003 in a rainfed field located in Sádaba, Zaragoza, Spain (42°17'N, 2°25'E). The average rainfall over the seven year study period was 197 ± 105 mm from sowing to harvest. The texture of the soil was a fine sandy-loam, and its main characteristics were: pH (H₂O) 7.95, Electric conductivity 0.29 dSm⁻¹, Organic matter 26.7 g kg⁻¹, P (Olsen) 21.9 mg kg⁻¹ and K (ammonium acetate) 327 mg kg⁻¹. A rotation (fallow-barley-vetch-durum wheat) was established in two contiguous plots (Table 1). Barley cv. Camelot was used in 1997 and 1998, Graphit in 2001, Hispanic in 2002 and Anton durum wheat in 1999, 2000 and 2003. Sowing density was 170 kg ha⁻¹ (450 seeds m⁻²) for barley, 180 kg ha⁻¹ (400 seeds m⁻²) for durum wheat and 100 kg ha⁻¹ (180 seeds m⁻²) for vetch. The row space was 15 cm.

This rotation is a modification of the local practice (cereal-fallow), including a vetch crop (cv. Senda), which is incorporated in the soil as green manure. Both stubble and cereal straw were also incorporated in the soil after the harvest. To replicate the conditions of conventional and organic systems, plots were divided into 90 m² subplots according to a split-plot design

with two factors: fertilization and weeding with three levels per factor. Levels of fertilization applied in each factor are briefly described below:

a) Main factor (fertilization): F1: Control without fertilization; F2: Organic fertilization: 2500 kg ha⁻¹ of compost made by cereal straw and sheep manure applied at preplant (moisture: 33.3%, organic matter: 57.4%, C: 27.8%, N: 2.9%, P₂O₅: 1.4%, K₂O: 5.1% and Na: 0.89%), and F3: Mineral fertilization (100 N- 60 P₂O₅- 60 K₂O kg ha⁻¹, from 1997 to 2000 and 70 N-60 P₂O₅- 60 K₂O kg ha⁻¹ from 2001 to 2003, with the N applied preplant and at tillering.

b) Secondary factor (weeding): E1: control without weeding; E2: mechanical weeding using a flex-tine harrow (made by Hatzenbichler, St. Andrä, Austria, along the sowing lines during the cereal tillering), and E3: chemical weeding using a herbicide that was chosen depending on the weed types.

The cropping systems analyzed in the experiment were called minimum input (no fertilization and no weeding, F1 and E1), organic (organic fertilization and mechanical weeding, F2 and E2) and conventional (chemical fertilizer and chemical weeding, F3 and E3). Fungicides are not used in the organic system because they are not needed under such semiarid conditions.

Economic analysis

For the economic part of the analysis, we separately present the operational costs, the incomes and the net margin for the three cropping systems defined by the combination of fertilization and weeding method. The purpose was to facilitate the correct understanding of the relevance of each component on the final farm profitability.

The minimum input system could be considered as organic since it maintains soil fertility by rotating with legumes and burying the stubble and cereal straw (Lacasta & Meco, 2006). In such case, subsidies could be obtained and the grain could be sold on the organic market. This scenario will be cited as "Minimum (org)" case. By contrast, in the absence of an organic market, the grain from the organic system would have to be sold on the conventional market. We also consider this scenario as "Organic (con)". Therefore, we evaluated the economic results of five alternatives: conventional, minimum input, minimum (org), organic and organic (con).

Table 1 - Crop rotation followed during the trials.

	1996-1997	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003
Plot 1	Barley→	Vetch→	Durum wheat→	Fallow→	Barley→	Vetch→	Durum wheat
Plot 2	Fallow→	Barley→	Vetch→	Durum wheat→	Fallow→	Barley→	Vetch

Costs

Table 2 shows the operational costs considered for our economic analysis. In order to simplify the data presentation we considered both input and application costs jointly. In the case of the input costs, we used the database in the area when available (MAPA, 1998-2004) and for the application costs, we also calculated the labour costs for some of the machinery operations in each system like harvesting, harrowing etc. (Arnal, 1990; Hernanz et al., 1992; Gil Martínez et al., 1994).

Incomes and margins

Cereal prices (Table 3) were taken from the *Lonja Agropecuaria del Ebro* (Ebro Agricultural Market) and the Committee on Ecological Agriculture of Aragon. Yield levels over a five year period (Table 4) are in terms of each management system. The income (Figure 2) of each production system included the value of the grain and subsidies from the European Common Agricultural Policy (CAP) in terms of farmed surface area and organic production.

We also calculated the cereal incomes according to annual subsidies (€ tm^{-1}) from the CAP for herbaceous crops and set-aside (MAPA, 1996; Commission Regulation, 1999), according to reference outputs (in tm ha^{-1}) provided by the government in the study areas (BOE, 1999) (Table 5).

European regulations provide subsidies for the cultivated surface area and also establish set-aside requirements. The plots in this study were subsidised since there was a rotation with fallow or vetch, as required by the CAP. The percentage of set-aside with respect to the surface area sown is normally 10% (in our case 0.1 ha) and is used to calculate the total subsidy per farm (although it can vary slightly per annum).

In 1999, 2000 and 2003 there was an additional payment since the province of Zaragoza was considered as a traditional producer of durum wheat. All CAP subsidies were the same for all systems and years, and somewhat higher for durum wheat (Figure 2, grey bars).

For the specific case of organic productions, the subsidies provided by the Government of Aragón were 21.63 € ha^{-1} in 1997, 25.84 € ha^{-1} to 30 € ha^{-1} in 1999

Table 2 - Cost calculated for several agricultural tasks performed during each trial and year.

Work description	Year						
	96-97	97-98	98-99	99-00	00-01	01-02	02-03
	----- € ha^{-1} -----						
1 Cultivator tillage	24.6	26.1	28.2	29.8	31.1	32.6	34.6
2 Soil bed preparation	24.6	26.1	28.2	29.8	31.1	32.6	34.6
3 Sowing of cereal	60.4	63.6	69.2	70.8	68.0	69.9	76.3
4 Harvest, straw chopping and storage	33.3	34.5	36.0	37.8	38.6	39.9	41.5
5 Burying of stubble	24.6	26.1	28.2	29.8	31.1	32.6	34.6
6 Fallow tillage	51.7	-	-	62.0	64.5	-	-
7 Soil bed preparation for vetch	-	26.1	28.2	-	-	32.6	34.6
8 Sowing of vetch	-	56.1	58.9	-	-	66.9	71.8
9 Chopping vetch	-	13.7	14.4	-	-	16.9	17.9
10 Soil incorporation of vetch	-	54.7	58.9	-	-	68.3	72.1
11 Organic fertilization	190.8	193.1	196.2	198.5	200.9	204.2	207.1
12 Mechanical weeding	10.1	10.7	11.6	12.2	12.7	13.4	14.1
13 Preplant mineral fertilization	78.6	80.1	82.6	83.2	83.8	84.6	85.4
14 Top dress mineral fertilization at tillering	30.6	42.8	43.6	44.2	30.0	30.8	31.6
15 Herbicide application	25.5	23.3	32.4	33.2	61.1	47.0	55.3
Total cost	554.8	677	716.6	631.3	652.9	769.3	811.5

Table 3 - Cereal price for conventional and organic markets.

Market/Year	1997	1998	1999	2000	2001	2002	2003
	----- € ha^{-1} -----						
Conventional	0.138	0.138	0.150	0.144	0.126	0.126	0.156
Organic	0.210	0.210	0.228	0.240	0.210	0.180	0.192

Crop: barley: 1997, 1998, 2001 and 2002. Durum wheat: 1999, 2000 and 2003

Table 4 - Yield of winter cereals from 1997 to 2003 in cropping systems.

Year/system	Minimum	Organic	Conventional
	----- kg ha ⁻¹ -----		
1997 (barley)	2650 a	2701 a	2542 a
1998 (barley)	3836 a	3757 a	3567 a
1999 (durum wheat)	1222 a	944 a	988 a
2000 (durum wheat)	2819 a	2840 a	2922 a
2001 (barley)	883 a	646 a	789 a
2002 (barley)	1497 a	1576 a	1306 a
2003 (durum wheat)	2819 a	3173 a	3429 a
Average (barley)	2216	2170	2051
Average (durum wheat)	2287	2319	2446
Average (barley and durum wheat)	2247	2234	2220

Differences between systems followed by the same letter were not significant, LSD test ($p > 0.05$).

Table 5 - European Common Agricultural Policy (CAP) subsidies in different years in the Sádaba area (Aragon, Spain).

Year	Cereal	CAP set-aside	Durum wheat
	----- € ha ⁻¹ -----		
1997	124.87	173.85	-
1998	135.85	172.07	-
1999	135.85	172.07	226.95
2000	146.68	146.68	218.85
2001	157.50	157.50	-
2002	157.50	157.50	-
2003	157.50	157.50	206.80

and 2000, and 92.32 € ha⁻¹ in 2001, 2002 and 2003 (Villa, 2002). These amounts were also used to calculate the total income of the organic system, although there can be slight variations depending on the government departments (Figure 2, black bars).

Finally, the net margins were calculated as the difference between the total incomes (from crops, subsidies and CAP payments) and costs (for operations, inputs, renting machineries, labour, etc.) of a typical farm. We did not consider repayments for capital, taxes or insurance (Figure 3).

RESULTS AND DISCUSSION

Yields were similar for the three systems, especially in the first six years (Table 4). The high levels of initial fertility of the soil help to explain why there was no increase in the harvest after adding different fertilizers (i.e., the amount provided was low in relation to the soil conditions). However, as the experiment covers an exceptional long time period, we could also state that the rotation applied was adequate and therefore, fertilization and chemical weed control are not justified from a productive perspective under the trial conditions. Moreover, we obtained similar results in a previ-

ous study including 25 analyses in eight locations in Spain with similar climatologically conditions over a four year period under normal soil fertility levels (Pardo, 2003). Of course, under these semiarid conditions, water is always the limiting factor and yields critically depend on the amount of rainfall in spring as stated by Moret et al. (2007) and Díaz-Ambrona & Mínguez (2001).

Weed density in the controls was variable but generally low (75 ± 71 annual plants m⁻²) with typical species found in winter cereals (*Lolium rigidum*, *Polygonum aviculare*, *Anacyclus clavatus*, *Papaver rhoeas*, *Fumaria officinalis*, *Veronica hederifolia*). Crops were not affected by diseases over the total trial period.

Economic results

To facilitate an adequate comparison of the economic results for the three systems, we have differentiated (Figure 1) the more relevant components of the total costs: mineral fertilizer and herbicide (black bars), compost manure and weed control (grey bars) and other operations (white bars). The costs for "other operations" are common for the three systems, and thus we can clearly distinguish the origin of the dif-

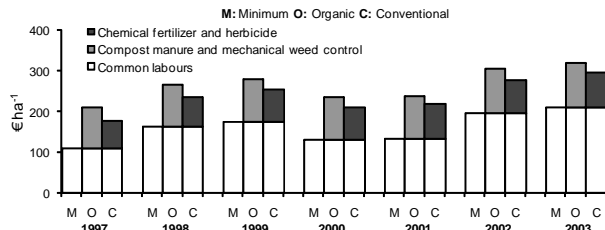


Figure 1 - Farm cost depending on year and agricultural system.

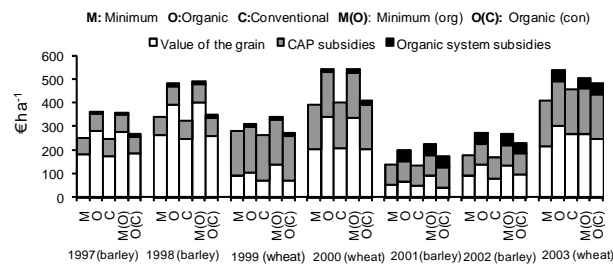


Figure 2 - Total income for a typical farm depending on year and agricultural system. Minimum (org): grain obtained in 'minimum input' system sold on an organic market. Organic (con) grain obtained in 'organic' system sold on a conventional market.

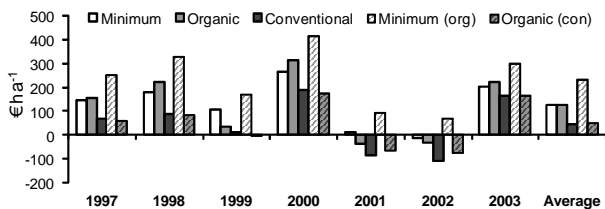


Figure 3 - Annual net margin for a farm depending on the agricultural system. Minimum (org): grain obtained in 'minimum input' system sold in an organic market. Organic (con): grain obtained in 'organic' system sold in a conventional market.

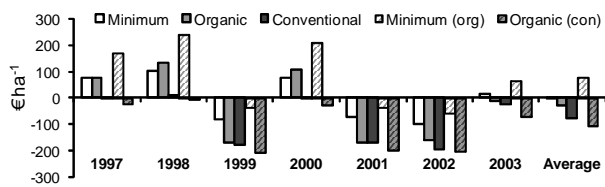


Figure 4 - Annual net margin for a farm depending on the agricultural system without subsidies. Minimum (org): grain obtained in 'minimum input' system sold in an organic market. Organic (con): grain obtained in 'organic' system sold in a conventional market.

ferences between systems. Costs were lower by using the minimum input system (not fertilization or weeding), and higher with the organic system in comparison to the conventional one (Figure 1). This result confirms the findings by Pimentel et al. (2005), who obtained an increase of 25-30% of costs in the organic system with respect to the conventional farming.

The compost was more expensive (0.06 € kg^{-1}) and more difficult to apply than the mineral fertilizer due to the type and dimension of the manure distributor needed for the application (slower than the mineral one). Moreover, mechanical weed control was cheaper than herbicide application (Table 2). The cost of herbicide application (Table 2) depends on the active ingredient applied every year in the farm, which was related to the type and amount of weeds found in each specific year. In the same way, the farm costs were less in 96-97, 99-00 and 00-01 than in 97-98, 98-99, 01-02 and 02-03 since the costs from neighbouring crops were lower in fallow than in vetch to bury.

Given that the yields were similar for the three systems, the value of the organic grain was higher because of its higher market price. Conversely, the income results for the minimum and conventional systems were similar (Figure 2). Therefore, since crop yield was similar, differences in margins were determined by differences in labour costs and market prices. Lower input costs in the minimum system were compensated by a higher sale price in the organic system. The economic margin of the organic option (266%) was similar to the minimum system (271%) and more than double of the conventional system (100%) (Figure 3). Meco et al. (1998), Lacasta & Meco (2006), (Agreda & Abós, 2001) emphasize that organic cropping systems are more profitable than conventional systems even without considering the higher market prices for organic products. Delate et al. (2003) obtained an increase of 25% in economic results for an organic system in relation to conventional agriculture with more profitable crops (corn-oat-alfalfa) and more favourable climate conditions.

Assuming a higher market price, the margins of the minimum input system (minimum (org), Figure 3) improve substantially (496%), almost five times higher than the conventional option. On the other hand, if the organic cereal is sold at the conventional price (organic (con), Figure 3), it is just as profitable (103%). In such a case, if specific subsidies for organic agriculture are not considered, an organic system would be the worst option because the costs of organic fertilization and weeding (application of the compost and flex tine harrowing) are not compensated by yield increase.

Without subsidies, the minimum option would have been the most profitable if sold at organic price in four of the seven years of study (Figure 4). These results confirm that conventional and organic agriculture are unfeasible without subsidies, even if the organic grain can be sold at a higher price. These results are important if we consider that the trend from the last reform in 2003 is to cut subsidies in the scope of the CAP and the promotion of sustainable agriculture in semi-arid areas in Spain.

The organic system generates good economic results in years 1997, 1998, 2000 and 2003, but in average terms, the profitability of the organic system is similar to the minimum for the total period, even when considering the higher market price for organic crops (Figure 3). The reason is that the margin of the organic systems critically depends on the yield obtained and also on the high market prices. Thus, in the long term, the use of compost and mechanical weed control are not justified from the productive (Table 4) or economic points of view. It may be reliable in the case that the minimum system is not considered organic and compost had to be applied.

According to the average cereal price during the seven years of the study and the costs of each system, we would need 2,277 kg ha⁻¹ of cereal to pay for the costs of minimum system, 2,517 kg ha⁻¹ for the cost of the organic system, and 3,409 kg ha⁻¹ for the costs of the conventional system. None of these values was obtained, especially for the conventional option (Table 4).

Current agricultural practices in semiarid areas are similar to a minimum system since farmers have substantially decreased the use of fertilizers and herbicides. Usually nitrogen fertilizers are applied at tillering if the water content in the soil during winter is adequate, while herbicides are not applied if there are no special problems. These farming practices and the results of our study suggest that minimum production can be easily adopted since yield can be maintained using the crop rotation proposed. Furthermore, the minimum system can legally obtain the subsidies for organic farming and also contributes to diminish the environmental impacts of agriculture because it reduces the petroleum dependence. In this sense, the current study has to be completed by a further analysis on the environmental effects of the three systems. As pointed out by Laurent et al. (2003) and Pardo et al. (2008), the correct evaluation of the agricultural activities should consider the economic, social and environmental aspects.

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